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SUSY FLAVOR v2.5: a computational tool for FCNC and CP-violating processes in the MSSM

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Abstract

We present `SUSY_FLAVOR` version 2.5 — program that calculates over 30 low-energy flavor observables in the general R-parity conserving MSSM. Comparing to previous versions, in `SUSY_FLAVOR` v2.5 parameter initialization in SLHA2 formats has been significantly generalized, so that the program accepts most of the output files produced by other libraries analyzing the MSSM phenomenology. Number of bugs and inconsistencies have been fixed, based on users feedback. Calculations of several processes implemented in earlier versions have been corrected. New processes of rare decays of the top quark to Higgs boson have been included. Variables controlling inclusion of contributions from various MSSM sectors have been added. Full updated manual of `SUSY_FLAVOR` v2.5 integrating the details of the modifications listed below can be found at `arxiv.org/abs/arXiv:1203.5023`.

NEW VERSION PROGRAM SUMMARY

Program Title: SUSY FLAVOR v2.5
Authors: J. Rosiek, P. Chankowski, A. Crivellin, A. Dedes, S. Jäger, P. Tanedo
Programming language: Fortran 77.
Computer: Any.
Operating system: Any, tested on Linux.
Keywords: Supersymmetry, K physics, B physics, rare decays, CP-violation.
PACS: 12.60.Jv, 13.20.He.
Classification: 11.6.
Catalogue identifier of previous version: AEGV_v2_0
Journal reference of previous version: Comput. Phys. Commun. 184 (2013) 1004
Does the new version supersede the previous version?: Yes

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Nature of problem:
Predicting CP-violating observables, meson mixing parameters and branching ratios for set of rare processes in the general R-parity conserving MSSM.
Solution method:
We use standard quantum theoretical methods to calculate Wilson coefficients in MSSM and at one loop including QCD corrections at higher orders when this is necessary and possible.
Reasons for the new version:
The input/output routines have been rewritten to make them more flexible and compatible with the SLHA2 standard [1]. Calculations of the several processes implemented in earlier `SUSY_FLAVOR` versions have been corrected. New observables have been added. Number of bugs have been corrected.
Summary of revisions:
1. Modified initialization routines. Currently the program should be able to read without modifications most of the SLHA2-compatible output files produced by other publicly available libraries calculating observables related to the MSSM phenomenology. In addition, new optional input block `SFLAV_HADRON` has been defined to facilitate modifications of the parameters related to the hadronic and QCD sector.

The initialization sequence goes now through the following steps:

- Before reading the file, all parameters are set to some initial values (which can be changed by editing the values given in the subroutine `sflav_defaults` in file `sflav_io.f`).

- Subsequently, the user-defined data are read from the file with the default name `susy_flavor.in`. Data are grouped in Blocks following the SLHA2 specification or extensions described in [2]. Blocks are read in the following order: `SOFTINP`, `SMINPUTS`, `VCKMIN`, `MINPAR` ($\tan\beta$ only, other entries are ignored), `EXTPAR`, `IMEXTPAR`, `MSL2IN`, `IMMSL2IN`, `MSE2IN`, `IMMSE2IN`, `TEIN`, `IMTEIN`, `TEINH`, `IMTEINH`, `MSQ2IN`, `IMMSQ2IN`, `MSU2IN`, `IMMSU2IN`, `MSD2IN`, `IMMSD2IN`, `TUIN`, `IMTUIN`, `TUINH`, `IMTUINH`, `TDIN`, `IMTDIN`, `TDINH`, `IMTDINH`, `SFLAV_HADRON`.

- Presence of *any* Block is optional - if some Block is absent, program falls back to default parameter values. At least flavor-diagonal SUSY mass parameters have to be defined, otherwise the vanishing default values cause program to crash.

- If a parameter is multiply defined in several Blocks, the value from Block read as latest in the list above overwrites (without warning!) the values from preceding Blocks.

- Blocks do not need to be complete and to contain all entries described in the SLHA2 specification - it is sufficient to define a minimal set of the parameters relevant for a given problem, others are filled with the default values.

- The "non-holomorphic" LR mixing terms are not included in the SLHA2 specification and by default set to 0. They can be initialized to the non-trivial values in the blocks `TXINH` and `IMTXINH` ($X = E, D, U$)

- New input block `SFLAV_HADRON` allows to modify hadronic- and QCD-related quantities used by `SUSY_FLAVOR`. The structure of this block and the default values of hadronic parameters are shown at the end of sample input file `susy_flavor.in` attached to the `SUSY_FLAVOR` distribution.

2. New control variables has been added, allowing to separately switch contributions from various MSSM sectors on or off. They can be set by the following statement at the beginning of the driver program:

`call set_active_sector(ih,ic,in,ig)`,

where the variables `ih, ic, in, ig` can take values 0 or 1 and they control, respectively, the inclusion in the total result the diagrams with gauge and Higgs bosons, charginos, neutralinos and gluinos exchanged in the loops. Note that diagrams with Higgs and gauge bosons are always added together and currently cannot be disentangled, so setting `ih=1, ic=in=ig=0` does not reproduce the SM result. By default, if no call to `set_active_sector` is made, all control variables are assumed to be equal to 1, so that all contributions are included.

3. Added or modified processes:

- The expressions used to calculate the neutron Electric Dipole Moment have been modified.

- The branching ratios for the radiative decays of the heavy lepton into the lighter lepton and the photon, $\mu \to e\gamma$ and $\tau \to e\gamma$, $\mu\gamma$, are now normalized to the total heavy lepton decay width (previously they were normalized to the decay width into leptonic channels).

- The routines calculating branching ratios of $B \to \tau\nu$ and $B \to D\tau\nu$ decays have been generalized to include more general structure of the effective Higgs boson-fermion couplings. In addition the routine calculating $Br(B \to D^\star\tau\nu)$ has been added.

- The routines for rare decays of the top quark to the CP-even Higgs boson and the light quarks, $t \to ch, uh$, have been added, based on Ref. [3] (program can calculate also the decay rates of the top quark to the heavier CP-even Higgs boson H, assuming that such decays are allowed kinematically).

- The routine calculating the approximate 2-loop estimate of the neutral CP-even Higgs mass m_h has been added, based on Ref. [4]. Note that for the more precise calculations of this mass other publicly available SUSY codes should be used.

- Default values of numerous quantities which are treated by `SUSY_FLAVOR` as the external parameters, mainly the values of hadronic parameters obtained from lattice calculations and results of experimental measurements, have been updated to accommodate the latest published results.

4. `SUSY_FLAVOR`'s output is now written to the file named `susy_flavor.out`. It has "SLHA-like" structure, i.e. it is divided into "data blocks", however these blocks are `SUSY_FLAVOR` specific and do not follow the common SLHA2 standards. The output file contains the following data blocks:

- `SFLAV_CONTROL`: control variables and error code status.

- `SFLAV_MASS`: MSSM mass spectrum after mass matrix diagonalization.

- `SFLAV_CHIRAL_YUKAWA`: relative size of the resummed chiral corrections to the Yukawa couplings.

- `SFLAV_CHIRAL_CKM`: relative size of the resummed chiral corrections to the CKM matrix elements.

- `SFLAV_DELTA_F0`: $\Delta F = 0$ observables: leptonic EDMs and $g-2$ anomalies, neutron EDM.

- `SFLAV_DELTA_F1`: $\Delta F = 1$ observables: decay rates of $l \to l'\gamma$, $K \to \pi\bar{\nu}\nu$, $B^+ \to \tau^+\nu$, $B \to D\tau\nu$, $B \to D^\star\tau\nu$, $B \to X_s\gamma$, $B_{d,s} \to l_i^+ l_j^-$, $t \to uh$, $t \to ch$.

- `SFLAV_DELTA_F2`: $\Delta F = 2$ observables: ϵ_K, Δm_K, Δm_D, Δm_{B_d}, Δm_{B_s}.

Blocks `SFLAV_CHIRAL_YUKAWA` and `SFLAV_CHIRAL_CKM` show the relative differences of bare and physical Yukawa couplings and CKM matrix elements

after the resummation of chiral corrections. If they are large, $\geq \mathcal{O}(1)$, the perturbation expansion is not reliable and the remaining program output may not be correct.

5. The full updated manual for `SUSY_FLAVOR` v2.5 has been created, integrating the detailed description of the modifications listed above. It can be downloaded at the address `arxiv.org/abs/arXiv:1203.5023`. Regular code distribution updates and bug fixes (between the major revisions submitted to Computer Physics Communications) can be found on the program web page `www.fuw.edu.pl/susy_flavor`.

Restrictions: The results apply only to the case of MSSM with R-parity conservation and without heavy right neutrino sector [5].
Running time: For a single parameter set below 1s on a personal computer.

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